A PRECISION DETERMINATION OF THE K-SHELL
INTERNAL CONVERSION COEFFICIENT OF THE
135.5 keV M⁴ TRANSITION IN ¹⁹³ᵐPt

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A PRECISION DETERMINATION OF THE K-SHELL
INTERNAL CONVERSION COEFFICIENT OF THE
135.5 keV M4 TRANSITION IN $^{193m}$Pt

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Date approved by Chairman: JUL 23 1976
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SUMMARY

This research involves an experimental study of the K-shell internal conversion coefficient of the 135.5 keV M4 transition in $^{193m}$Pt decay by the XPG (x-ray per gamma ray) technique. A separate measurement of $^{195m}$Pt was undertaken in order to correct its contribution to the $^{193m}$Pt K x-ray spectrum.

The radioactive sources of 4.4 day $^{193m}$Pt and 4.02 day $^{195m}$Pt were prepared by thermal neutron irradiation respectively of 57.3% enriched $^{192}$Pt and 97.4% enriched $^{194}$Pt in the Georgia Tech Research Reactor. These measurements have been made with a high resolution, high efficiency lithium drifted Germanium Ge(Li) detector. This detector was used in conjunction with a Nuclear Data 2200 single parameter analyzer with 2048 channels and 100 MHz ADC units.

The value of the K-shell conversion coefficient of the 135.5 keV M4 transition in $^{193m}$Pt was determined for the first time to be $\alpha_K = 135.2 \pm 10.5$. This result is in agreement with the theory of Hager and Seltzer within the experimental uncertainties. However, a closer examination shows a deviation of the value of 3.4% below the theoretical results of Hager and Seltzer. This deviation has been systematically observed by Raman et al. in other pure M4 transitions.
CHAPTER I

INTRODUCTION

A nuclear electromagnetic transition from an initial state with energy $E_i$ to a final one with energy $E_f$ can take place by the emission of a gamma ray or of an orbital electron called an internal conversion electron.

A third process, internal pair creation, can occur when $E_i - E_f > 1022$ keV, but this process is absent in the present experiment. The energy of the emitted gamma ray is $E_\gamma = E_i - E_f$, while that of the conversion electron is $E_{ce} = E_\gamma - B_K$, where $B_K$ is the binding energy of the electron from the K shell. The ratio of the electron to gamma emission rate, $\alpha = \frac{N_e}{N_\gamma}$, is defined as the internal conversion coefficient. Partial internal-conversion coefficients are used in connection with electron emission from specific shells; for example, $\alpha_K = \frac{N_{eK}}{N_\gamma}$ is the coefficient for ejection of electron from the K shell, and the sum of the partial coefficients is $\alpha_{TOT}$.

Measurements of conversion coefficients are of practical importance. For example, they are used in studies of biological effects of radioactivity and in making calculations of shielding requirements. Such measurements are
of scientific importance in assigning nuclear transition multipolarities, which in turn lead to spin and parity assignments. The use of conversion coefficients in assigning multipolarities and establishing spin and parities has been discussed by Hamilton\(^1\) and by Graham.\(^2\)

Conversion coefficients depend on the following:
1. transition multipolarity;
2. electric or magnetic character of the transition;
3. transition energy;
4. atomic number, \(Z\), of the nucleus in which the transition occurs;
5. the shell or sub-shell from which the electron is ejected; and
6. to a small degree also on the structural details of the nucleus.\(^3\)

The theory of internal conversion has recently been summarized by Pauli, \textit{et al.}\(^4\) The first calculations for the K-shell were prepared by Rose, \textit{et al.}\(^5\) on the basis of relativistic electron wave functions for a point charge nucleus and pure Coulomb field; screening of atomic electrons was not taken into account. However, a calculation by Reiz\(^6\) has shown that the screening of the nuclear Coulomb field by a Thomas-Fermi potential affects the results for the K-conversion coefficients only slightly; but the conversion coefficients for the L- and higher shells proved to be quite sensitive to screening by the inner electrons. As early as 1951, Sliv\(^7\) had shown that the assumption of a point nucleus was not sufficient in some cases, particularly for the magnetic dipole (M1) transition in heavy nuclei.
where the conversion coefficients depend on the finite nuclear size. Experimental results soon verified the effect for K- and L-shell conversion for M1 transitions in heavy elements. This opened a new area for comparison of theory and experiment.

Theoretical calculations for both the K- and L-shells were done by Sliv and Band and Rose taking into account atomic screening by use of the Thomas-Fermi-Dirac screening function, and finite nuclear size by assuming a uniformly charged nucleus of radius \( R = 1.2 \times 10^{-13} \text{ cm} \). These authors differ in their treatment of the so-called penetration terms, which arise from nuclear interactions of the conversion electron. Sliv et al. evaluated the penetration terms by assuming a model in which the nuclear transition current lies on the spherical nuclear surface, while Rose set the penetration terms equal to zero. In most cases the conversion coefficients for finite sized nuclei are smaller than those calculated for a point nucleus with larger reductions occurring for higher \( Z \) values, particularly for M1 transitions. Recalculations were done by Hager-Seltzer and by Pauli, and these agreed better with Sliv and Band than with Rose.

A systematic comparison between the tables of Sliv and Band and Rose shows that most of the discrepancies are the result of numerical interpolation errors in the latter.

The most recent tables are those calculated by
Hager-Seltzer and by Pauli. The former include the effect of finite nuclear size without penetration. The nucleus is taken to have a uniform charge distribution with radius
\[ R = 1.2 \times 10^{-13} \text{ cm}, \]
and the atomic screening is expressed by a relativistic self-consistent electron potential of the Hartree-Fock-Slater type (RHFS), and in place of the original Slater prescription—the corrected values of Kohn are used. The energies of the conversion electrons are evaluated from experimental binding energies which are more accurate than theoretical binding energies. The electron-nucleus interaction is corrected for vacuum polarization. This effect, according to Hager and Seltzer, decreases the M\text{1} conversion coefficient in the K-shell by about 1%.

The tables of Pauli are calculated with a Thomas-Fermi-Dirac potential with the inclusion of a finite nuclear size effect, and the energies of the conversion electrons are computed by using calculated binding energies.

The tables of Hager and Seltzer are the most widely used since exact calculation for many values of Z and energies are made, resulting in simpler and more accurate interpolation.

Recently, a summary of measured E\text{3} and M\text{4} conversion coefficients having accuracies better than 5% have been published by Raman et al., who concluded that experimental values of \( \alpha_K \) are 2-3% lower than the theoretical ones taken from the Hager and Seltzer tables. More recently, Campbell
et al. concluded that this 3% discrepancy for M4 transitions reported by Raman, et al. can be reduced to 0.8% by using the RHFS wave functions with the Rosen-Lindgren exchange potentials. The number of precise measurements was insufficient to decide whether or not this discrepancy is a function of Z or of the transition energy. This led us to measure the K-shell conversion coefficient \( \alpha_K \) of the M4 transition in \(^{193}\text{m} \text{Pt} \), which decays to the ground state with a half-life of \((4.4 \pm 0.2 \text{ days})\), and a transition energy of \((135.5 \pm 0.03) \text{ keV} \).

Although there is no previous measurement available in the literature for \( \alpha_K \), Svahn et al. determined the conversion electron intensity ratios, in order to obtain a multipolarity assignment of M4, and in the present work, the absolute K conversion coefficient \( \alpha_K \) was determined by the XPG (x-ray per gamma ray) technique.
CHAPTER II

EXPERIMENTAL METHOD

A. Basis of the Experimental Method

K X-ray to Gamma Peak Method (XPG Method)

In measuring a K-conversion coefficient we can use the fact that each K-conversion electron leaves the atom in an excited state with one hole in the K-shell which then decays with emission either of a K x-ray or a K-Auger electron. The conversion electron intensity can be obtained from the K x-ray intensity by correcting for the K x-ray fluorescence yield, \( \omega_K \), the fraction of the K-shell vacancies which decay with emission of a K x-ray.

\[
\omega_K = \frac{I_K}{n_K}
\]

(1)

where \( I_K \) is the total number of a characteristic K x-ray photons emitted from a sample, and \( n_K \) is the number of primary K-shell vacancies, equal to the number of emitted K-conversion electrons.

The K-conversion coefficient, \( \alpha_K \), can be obtained from the relation

\[
\alpha_K = \frac{(I_{K\alpha} + I_{K\beta})}{\omega_K I_\gamma}
\]

(2)
where \( I_{K\alpha} \), \( I_{K\beta} \), and \( I_\gamma \) are the respective x-ray and gamma ray intensities corrected for efficiencies, and \( \omega_K \) is the K x-ray fluorescence yield.

The value of \( \omega_K \) is available in the literature, but for this application, it is important that \( \omega_K \) has been independently determined by a method other than XPG, so that the value of \( \omega_K \) used in Eq. 2 is independent of \( \alpha_K \).

In order to measure the intensity of K x-rays relative to the gamma ray, one must carry out an efficiency calibration of the Ge(Li) detector. In the case considered here, we were interested in the low energy region (60 to 392 keV) and standard sources were used as discussed in the efficiency section below.

**B. Source Preparation**

Pt powder enriched to 57.3% \(^{192}\text{Pt}\) was obtained from Oak Ridge National Laboratory. A 2.5 mg amount of the enriched isotope was sealed in the center of a polyethylene disk. The radioactive source was prepared via the reaction \(^{192}\text{Pt} (n,\gamma) \(^{193}\text{mPt}\) (4.4 days) by irradiating the disk in a flux of \(1 \times 10^{13} \text{n/cm}^2 \text{sec}\) for one hour in the Georgia Tech Research Reactor. The 18 hour \(^{197}\text{mPt}\) by-product was allowed to decay.

Sources of 4.02 day \(^{195}\text{mPt}\) were also prepared by the same method, using Pt powder enriched to 97.4% \(^{194}\text{Pt}\). The resulting source intensities were about 17 \(\mu\text{ci}\) for \(^{193}\text{mPt}\).
and 5 μCi $^{195}$Pt. These sources were relatively thin to eliminate self-absorption of x rays in the source.

C. Detector Efficiency Calibration

The measurements of x- and gamma ray singles spectra from $^{193}$Pt and $^{195}$Pt sources were carried out by using a high-resolution, high-efficiency, cooled, Princeton Gamma-Tech Ge(Li) detector with an active diameter of 38.0 mm and an active depth of 14 mm. This detector has a resolution of 760 eV FWHM for the 122 keV gamma of $^{57}$Co; a peak-to-Compton ratio of 32.4:1; and a nominal efficiency of 6% relative to that 7.5 x 7.5 cm NaI(Tl) crystal, for 1332 keV gamma ray of $^{60}$Co at a source-to-window distance of 25 cm. A Canberra model No. RG-11c preamplifier and model 1412 main amplifier were used. This detector was used in conjunction with a Nuclear Data 2200 single-parameter analyzer with 2048 channels and 100 MHz ADC units. Output of the 2200 analyzer was available on punched paper tape, typewriter printout, and a point plotter.

Shielding and source mounts were constructed to minimize the background radiation and to maintain a fixed geometry. The shielding system was an 11.2 cm diameter annulus consisting of 12.7 mm Al, 6.1 mm brass, and 1.91 cm Pb, graduated from the inside out. The source and the detector face were completely surrounded by 5 cm Pb bricks. The source mount consists of a machined plexiglass cylinder.
which permitted the use of various source-to-detector distances.

The use of the XPG method requires accurate determination of photopeak gamma and x-ray intensities. It was necessary to determine the relative efficiency of the Ge(Li) detector used in this work. The detector photopeak response curve was established with a set of calibrated gamma ray sources of known activity consisting of $^{241}$Am, $^{57}$Co, and $^{203}$Hg obtained from the Laboratory of Metrology for Ionizing Radiations of the French Atomic Energy Commission, and $^{57}$Co, $^{203}$Hg, $^{109}$Cd, $^{139}$Ce, and $^{113}$Sn were obtained as a mixed source from the National Bureau of Standards Center for Radiation Research. The French sources were placed individually at a fixed distance (8 cm) on a fixed plexiglass holder aligned with the axis of the window of the Ge(Li) detector. The mixed sources were placed at the same distance, and the efficiency points of $^{57}$Co and $^{203}$Hg of the mixed sources were normalized to the points from the French sources for $^{57}$Co and $^{203}$Hg. The activity and the decay characteristics of these standard sources are known to accuracies of from 2 to 4%.

The efficiency of the detector was calculated by

$$\epsilon(E) = \frac{C(E)}{N(E) N_0}$$

where $\epsilon(E)$ is the photopeak efficiency of the detector for a gamma ray of energy $E$, $C(E)$ is the number of counts per
second detected in the photopeak of energy $E$, $N_{(E)}$ is the number of photons of energy $E$ emitted per disintegration, and $N_0$ is the disintegration rate per second of the standard source. The detector photopeak response curve gives the relative full energy peak detection efficiencies of the Ge(Li) detector as a function of photon energy.

Fig. 1 shows the efficiency response curve of the Ge(Li) detector. The curve is typical of this type of detector. The drop-off at low energy is due to photon absorption in air, the Be window, gold contact layer and in the insensitive Ge dead layer, while the drop off at high energy is due to the decreasing photoelectric cross section with energy.\textsuperscript{22,23}
Figure 1. Efficiency of the Ge(Li) Detector Measured at 8 cm from the Be Window.
Table 1. Standard Sources Used in the Detector Efficiency Calibration

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Photon Energy (keV)</th>
<th>Photons Emitted (Per Decay)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{241}$Am</td>
<td>59.54</td>
<td>$0.359 \pm 0.006$</td>
</tr>
<tr>
<td>$^{57}$Co</td>
<td>121.97</td>
<td>$0.856 \pm 0.003$</td>
</tr>
<tr>
<td></td>
<td>136.33</td>
<td>$0.1075 \pm 0.003$</td>
</tr>
<tr>
<td>$^{203}$Hg</td>
<td>72.87</td>
<td>$0.0977 \pm 0.005$</td>
</tr>
<tr>
<td></td>
<td>82.50</td>
<td>$0.0273 \pm 0.002$</td>
</tr>
<tr>
<td></td>
<td>279.19</td>
<td>$0.8155 \pm 0.015$</td>
</tr>
<tr>
<td>$^{109}$Cd</td>
<td>88.036</td>
<td>-----</td>
</tr>
<tr>
<td>$^{139}$Ce</td>
<td>165.852</td>
<td>-----</td>
</tr>
<tr>
<td>$^{113}$Sn</td>
<td>391.689</td>
<td>$0.799 \pm 0.003$</td>
</tr>
</tbody>
</table>

a  AEC NBM (France)
b  NBS SRM-4215C Mixed Sources

Data extracted from references 23-25.
CHAPTER III

DATA ANALYSIS

A. Peak Analysis

The peak analysis in this work was done manually. A spectrum was plotted on a linear scale and the background was essentially horizontal, and was estimated by interpolation between both sides of the peak as follows.

The centroid position of the peak was determined, then the background from both sides was taken beyond the limits defined by one to two times the full-width-at-tenth-maximum (FW0.1M), to represent the true continuum on the high and low energy sides of the peak. The total number of counts in a given peak was determined by integrating within the peak limits, defined as the FW0.1M of the peak. The average of the background per channel on each side was determined and multiplied by the number of channels in the peak. This represents the background under the peak of interest and was subtracted. Doublets and multiplets were resolved by fitting known line shapes from well-resolved lines from standard sources of nearly the same energy.

B. $^{193}\text{mPt}$ and $^{195}\text{mPt}$ K X-ray and Gamma Ray Analysis

A typical $^{193}\text{mPt}$ singles spectrum is shown in Fig. 2. In addition to $^{193}\text{mPt}$ activity, the spectrum contained Ir
Fig. 2. X-Ray and Gamma Ray Spectrum from the $^{193}\text{mPt}$ Source

The decay scheme of $^{193}\text{mPt}$ and the singles x- and γ-ray spectrum from a source prepared by thermal neutron irradiation of 57.3% enriched $^{192}\text{Pt}$. Activities from $^{195}\text{Pt}$, $^{191}\text{Pt}$, and $^{199}\text{Pt}$-Au are also present from the irradiation, so that the correction procedures discussed in the text had to be applied in order to obtain the net relative intensities of K x rays and 135.5 keV γ-ray for $^{193}\text{mPt}$ decay.
\[ \begin{align*}
\text{15} & \quad 13/2^+ \\
\text{193m Pt} & \quad 149.78 \text{ keV} \\
\text{5/2}^- & \quad 14.27 \\
\text{M4} & \\
\text{3/2}^- & \quad 1.64 \\
\text{M1 + E2} & \\
\text{1/2}^- & \quad 0 \\
\text{EC} & \quad 50\gamma \\
\text{193g Pt} & \quad 78 115
\end{align*} \]
K x rays arising from the decay of $^{191}$Pt and Au, Hg K x rays from the decay of $^{199}$Pt and $^{199}$Au as well as the accompanying gamma rays.

Since the $K_\alpha_2$ peak of Ir and the composite (Pt $K_\alpha_2$ + Ir $K_\alpha_1$) peak are completely resolved, the Ir $K_\alpha_2$ x-ray intensity was determined and after correcting for the efficiency, the theoretical x-ray intensity ratios of Scofield\textsuperscript{26} for Ir ($K_\alpha_2/K_\alpha_1$), Table 2, were used to deduce the Ir $K_\alpha_1$ x-ray intensity. The latter was subtracted from the intensity of the composite (Pt $K_\alpha_2$ + Ir $K_\alpha_1$) peak to obtain the net Pt $K_\alpha_2$ x-ray intensity. A similar procedure was used to correct Pt $K\beta_1^+$ x-rays for the Ir $K\beta_2^+$ x-ray contribution. Finally, the Pt $K_\alpha_1$ and $K\beta_2^+$ x-ray peaks were corrected for Au $K_\alpha_2$, $K\beta_1^+$ contributions by using a similar procedure.

The Pt x rays were well resolved from the contaminant Hg K x rays, and no correction was required. The Pt K x-ray intensity ratios ($K_\alpha_2/K_\alpha_1 = 0.566$, $K\beta_1^+/K_\alpha_1 = 0.355$, $K\beta_2^+/K_\alpha_1 = 0.099$) for the resulting peaks were determined and compared to the theoretical intensity ratios of Scofield\textsuperscript{26} (Table 2). The agreement was well within the experimental uncertainties.

Due to the presence of 26% of $^{194}$Pt in the enriched sample of $^{192}$Pt, a correction for the $^{195m}$Pt contribution to the $^{193m}$Pt K x rays was needed. Therefore, a separate measurement of the activity of $^{195m}$Pt obtained via the $^{194}$Pt ($n,\gamma$) reaction was undertaken. A typical $^{195m}$Pt singles
Table 2. Theoretical K X-ray Intensity Ratios Used in the Correction of Pt K X-rays

<table>
<thead>
<tr>
<th>Element</th>
<th>$K_\alpha_2/K_\alpha_1$</th>
<th>$K_\beta_1'/K_\alpha_1$</th>
<th>$K_\beta_2'/K_\alpha_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ir</td>
<td>0.5827</td>
<td>0.3385</td>
<td>0.0959</td>
</tr>
<tr>
<td>Pt</td>
<td>0.5850</td>
<td>0.3399</td>
<td>0.0972</td>
</tr>
<tr>
<td>Au</td>
<td>0.5874</td>
<td>0.3414</td>
<td>0.0987</td>
</tr>
<tr>
<td>Hg</td>
<td>0.5899</td>
<td>0.3430</td>
<td>0.1004</td>
</tr>
</tbody>
</table>

*From J. H. Scofield, Ref. 26.*
spectrum is shown in Fig. 3. The 98.9 keV gamma ray in $^{195}\text{Pt}$ is intense and well resolved from the 96 keV gamma ray in $^{191}\text{Ir}$. The intensity ratio of the Pt K x ray to the 98.9 keV gamma ray from $^{195}\text{Pt}$ was determined and applied to the correction of the $^{193}\text{Pt}$ x rays for the $^{195}\text{Pt}$ x-ray contribution. An average value of $7.68 \pm 0.34$ was obtained for the ratio of $^{195}\text{Pt}$ (K x rays/98.9 keV gamma rays).

By normalizing to the 98.9 keV gamma ray from $^{195}\text{Pt}$ appearing in the $^{193}\text{Pt}$ spectra, the $^{195}\text{Pt}$ K x-ray contribution could be subtracted from the composite $^{193}\text{Pt} + ^{195}\text{Pt}$ K x-ray peak to obtain the net intensity of $^{193}\text{Pt}$ K x-rays.

The intensity of the 135.5 keV gamma ray, corrected for detector efficiency, was determined. The results of three measurements of the intensity ratio of the $^{193}\text{Pt}$ K x rays to the 135.5 keV gamma ray are reported in Table 2. The average value is $130.15 \pm 10.00$.

C. Evaluation of $\alpha_K$ and the Error Analysis

Accepting a value of the K-shell fluorescence yield as $\omega_K = 0.963 \pm 0.013$ from the recent review of Bambynek et al.\textsuperscript{27} and the average value of the intensity ratio of the $^{193}\text{Pt}$ K x ray to the 135.5 keV gamma ray from Table 3, the value of the K-shell conversion coefficient of the 135.5 keV M4 transition in $^{193}\text{Pt}$ was determined to be $\alpha_K = 135.2 \pm 10.5$. 

Fig. 3. X Ray and Gamma Ray Spectrum from the $^{195m}$Pt Source

The decay scheme of $^{195m}$Pt and the singles x- and gamma ray spectrum from a source prepared by thermal neutron irradiation of 97.4% enriched $^{194}$Pt. This spectrum was used to correct the spectrum of Fig. 2 for the presence of $^{195m}$Pt activity as described in the text.
Table 3. Measured Intensity Ratio $R$ of K x-ray to the 135.5 keV Gamma Ray in \textit{193}\textsuperscript{m}Pt Decay

<table>
<thead>
<tr>
<th>Run Number</th>
<th>$R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$130.80 \pm 9.60$</td>
</tr>
<tr>
<td>2</td>
<td>$129.98 \pm 10.58$</td>
</tr>
<tr>
<td>3</td>
<td>$129.66 \pm 9.90$</td>
</tr>
</tbody>
</table>

Average: $130.15 \pm 10.00$
The uncertainty associated with this value is due almost entirely to the interpolation of the background below the weak 135.5 keV gamma ray peak. The error was estimated as follows.

The systematic error in the intensity of a certain gamma or x ray is a result of the error in the half-lives, the error in the number of photons of given energy emitted per disintegration, and in the disintegration rate of the standard sources. These errors were added linearly to the weighted average of the statistical error and the background error for the intensity of each individual gamma or x ray of interest.

The uncertainty in the detector efficiency is ±5%. The error associated with $\alpha_K$ was evaluated by using the following equations.

$$\alpha_K = \frac{R \pm \sigma_R}{\omega_K \pm \sigma_{\omega_K}} \quad (3)$$

$$\sigma_{\alpha_K} = \alpha_K \sqrt{\left(\frac{\sigma_R}{R}\right)^2 + \left(\frac{\sigma_{\omega_K}}{\omega_K}\right)^2} \quad (4)$$

where $R, \sigma_R$ are the intensity ratio of the $^{193m}$Pt x rays to the 135.5 keV gamma ray and the uncertainty in $R$, respectively, $\omega_K$ is the K fluorescence yield, $\alpha_K$ is the uncertainty in $\omega_K$, and $\sigma_{\alpha_K}$ is the evaluated uncertainty in $\alpha_K$. 
CHAPTER IV

RESULTS AND DISCUSSION

The final result for the K-conversion coefficient for the 135.5 keV pure M4 transition in $^{193m}$Pt is:

$$\alpha_K = 135.2 \pm 10.5$$

At present the most reliable tabulation of internal conversion coefficients is that of Hager and Seltzer\textsuperscript{16} which is unique in several respects; for example, no Z-interpolations are used. Instead, coefficients were calculated at every Z value with relativistic self-consistent field wave functions. Furthermore, many values of transition energies were used so as to facilitate accurate energy interpolation even at low energy.

The theoretical prediction of $\alpha_K$ by Hager and Seltzer\textsuperscript{16} for the 135.5 keV M4 transition in $^{193m}$Pt was obtained with the interpolation program given by these authors and is $\alpha_K$ (theory)\textsuperscript{*} = 140. Our result is in good agreement with this value within the experimental uncertainties. However, a closer examination shows a deviation of 3.4% of the centroid

\textsuperscript{*}An accurate theoretical value cannot be interpolated from the tables of Pauli\textsuperscript{17}, because the number of points tabulated in this region of Z is insufficient to take account of the rapid change in $\alpha_K$ with energy below 150 keV.
value from the theoretical results. This deviation has been systematically observed by Raman et al.\textsuperscript{18} for several M4 cases with uncertainty of (±5%). Recently, Abreu et al.\textsuperscript{28} reported a similar deviation of (3 ± 5)% for the $\alpha_K$ coefficient of the 65 keV M4 transition in $^{119}\text{Sn}$. 

We can say that the theoretical K-conversion coefficients of Hager and Seltzer for M4 transition are accurate to 3%, and additional measurements of conversion coefficients, preferably with experimental accuracies of 1% or better, are necessary before one can conclude decisively that the theoretical value of Hager and Seltzer for M4 transitions are 2-3% higher than the experimental values. It is clear however, that the systematic trend of the most precise values of $\alpha_K$ for pure M4 transitions is in this direction.

The present result is the first measurement of the K-conversion coefficient for the 135.5 keV pure M4 transition in $^{193m}\text{Pt}$. If $^{192}\text{Pt}$ enriched to 95% or better is used, it might be possible to improve somewhat on the error limits of the present result.
REFERENCES


17. H. C. Pauli, *Tables of Internal Conversion Coefficients and Particle Parameters*, (Purdue University, 1967).


